Statistical Inference
- COURSE SYLLABUS

1.	**Course title:** Statistical Inference
2.	**Lecturer:** dr hab. Radosław Poleski, rpoleski@astrouw.edu.pl
3.	**Field, type and level of studies, year of study:** statistics, all years of study
4.	**Course character:** General interdisciplinary lecture
5.	**Teaching method:** In-person
6.	**Language:** English
7.	**Course type and number of hours:** Workshop, 3 lessons (each 45 min.) per week
8.	**Estimated load of student's independent work:** 15h
9.	**Total workload and number of ECTS points:** 60 h, 3 ECTS
10.	**Short description and main focus of the course:** The goal of the course is to prepare participants for conducting statistical inference using modern tools. The main topics of the course: • Monte-Carlo integration • importance sampling • Markov chain Monte-Carlo • nested sampling • hierarchical Bayesian statistics • Bayesian model selection • mixture models • Guassian processes Topics will be adjusted based on the participants interests.
11.	**References:** 1. Hogg, Myers, and Bovy 2010 „Inferring the Eccentricity Distribution", ApJ 725, 2166 2. Foreman-Mackey, Hogg, and Morton 2014 „Exoplanet Population Inference and the Abundance of Earth Analogs from Noisy, Incomplete Catalogs", ApJ 795, 64 3. Sharma 2017 „Markov Chain Monte Carlo Methods for Bayesian Data Analysis in Astronomy", ARA&A 55, 213 4. Ivezić et al. 2019 „Statistics, Data Mining, and Machine Learning in Astronomy: A Practical Python Guide for the Analysis of Survey Data", Princeton University Press

	5. Speagle 2019 „A Conceptual Introduction to Markov Chain Monte Carlo Methods", arXiv:1909.12313 6. Aigrain and Foreman-Mackey 2023 „Gaussian Process Regression for Astronomical Time Series", ARA&A 61, 329	
12.	**Prerequisites:** • probability theory • programming and data visualization - python is suggested but other languages are allowed	
13.	**Educational outcomes:**	**PQF level 8 codes:**
	Knowledge: Upon successful completion of the course, the learner will demonstrate advanced knowledge and understanding of: • Theoretical foundations and practical implications of Monte-Carlo integration and variance-reduction techniques, including importance sampling. • Principles, mathematics, and assumptions underpinning Markov Chain Monte Carlo, nested sampling, and hierarchical Bayesian models. • Bayesian model selection criteria, their interpretation, strengths and limitations in complex inference problems. • The structure and properties of mixture models and the role of Gaussian processes in modelling uncertainty and functions. • State-of-the-art literature and research developments in Bayesian statistics, including conceptual challenges and areas of active methodological research.	P8S_WG
	Practical Skills: Upon successful completion of the course, the learner will be able to: • Independently design and implement Monte Carlo and MCMC algorithms using modern computational tools to perform efficient statistical inference. • Apply nested sampling and importance sampling methods to estimate posterior distributions and model evidence in complex statistical models. • Develop and critically evaluate hierarchical Bayesian models. • Select and compare competing models using Bayesian model selection techniques and interpret the results in context. • Employ mixture models and Gaussian processes in data analysis, including implementation, tuning, and	P8S_UW, P8S_UO

	validation in programmes or software environments appropriate for advanced statistical computing.	
	Social Skills: Upon successful completion of the course, the learner will be ready to: • Critically reflect on the ethical, theoretical and practical implications of statistical modelling choices, including responsibility for transparent and reproducible analysis. • Communicate complex statistical concepts, results and their limitations effectively to both specialist and non-specialist audiences. • Work autonomously and collaboratively in research or professional teams to integrate advanced inference methods into interdisciplinary projects. • Engage in independent study and continuous professional development, synthesising new research findings with existing knowledge to drive innovation in statistical practice.	P8S_KK, P8S_KR
14.	**Evaluation of the educational outcomes:** homework assignments and oral exam	
15.	**Criteria to complete the course:** Active attendance – laptop for coding is required; homework assignments in the case of more than two classes missed.	
16.	**Contact with the lecturer:** email: rpoleski@astrouw.edu.pl in-person meeting (at Al. Ujazdowskie 4, room 3080) possible after making an appointment	